

# **Basic Wood Energy Information**

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Small- and moderate-sized communities in forested areas face danger from forest fires burning out of control. Even if fires are constrained to the forest and flames do not jump the boundaries to inhabited areas, damages are great.

In the Intermountain West, the severity and frequency of forest fires has increased due to drier seasons and an overabundance of dense, overstocked stands. This overabundance of material is the result of effective fire suppression and the high costs of harvesting and using small-diameter trees. If more of this material could be economically utilized, the risk of disastrous fires would be greatly reduced, vigorous forest growth would be sustained, and needed employment opportunities for economically disadvantaged rural residents would be provided.

Surplus woody growth and thinnings from more intensively managed stands could also be used as an alternative to fossil fuel. Possibilities include wood-fired power-generating plants, industrial applications of cogeneration systems for process heat and electricity, institutional space heating facilities, home heating, or conversion of wood to ethanol or other chemicals. For application in institutional and residential heating, manufacture of pellets could be an intermediate step. Power generation with wood generally requires higher capacity installations of 10 to 20 MW or more of electricity. This corresponds to 20 to 40 MW of thermal energy. Although such plants use larger quantities of wood fuel, smaller applications offer greater opportunities for implementation in the short term.

Institutions, such as schools, are likely choices for wood-burning facilities. Combustors to serve such needs might range in capacity from 0.3 to 3 MW of thermal energy, or 1 million to 10 million Btu/hour. Other rough equivalencies might be from 1,000 to 10,000 pounds of steam/hour or from 30 to 300 boiler horsepower. A boiler horsepower is equal to the evaporation of 34.5 pounds of water/hour from and at a feedwater temperature of 212°F, or is equivalent to 33,480 Btu/hour (9.81 kWth).

From 1978 to 1985, during the years of oil scarcities and high prices, many heating facilities using biomass material for fuel were installed in educational institutions in Michigan, Minnesota, Wisconsin, Idaho, Arkansas, Georgia, Kentucky, Missouri, Tennessee, Virginia, and Washington. In the 1990s, Pennsylvania, Vermont, and Maine put facilities into schools and the National Arbor Day Foundation installed a demonstration plant at their Lied Conference Center in Nebraska City, Nebraska. Some of these installations might also use other fuels as backup or for cofiring in wood-burning or separate facilities.

Facilities can use different types of combustors (including traveling grate, pile burner, suspension burner, and fluidized bed); boilers (including fire tube and water tube); exhaust-gas cleanup systems; and wood fuels (including whole tree chips, mill or plant residues, sawdust, pellets, and cordwood).

The costs of installation is highly variable because of the different types and capacities of equipment, as well as whether equipment is new or used or already in-place using alternate fuels but can be converted to burn wood. In the 1990s, a facility that burned wood in schools cost between \$118,000 and \$465,000. In 1999, the list price from one company for a fuel burner with a maximum energy input of 5 million Btu/hour was \$56,000. Today, complete wood fuel burner/boiler packages are estimated between \$50 and \$75 per pound of steam generation per hour, or \$50,000 to \$75,000 per million Btu/hour of heat input. An important aspect of wood energy is that a fossil fuel backup is typically installed for commercial units because of the required reliability.

Besides schools, other applications for low-capacity wood-burning facilities include hospitals, prisons, brick factories, greenhouses, foundries, offices, and shopping centers.

### **Example**

As mentioned previously, an example of a modern wood-burning system is the demonstration plant at the National Arbor Day Foundation's Lied Conference Center in Nebraska City. This plant consists of a bin with an auger and metering system for wood chip fuel, two industrial combustion three-pass fire-tube boilers designed to burn gas, two fireboxes to burn wood, underfire air, and a computerized control system. The fireboxes are set directly underneath the boilers. The boilers are rated at 115 to 230 boiler horsepower or 4,000 to 8,000 pounds of steam/hour. Steam is produced at about 100 lb/in<sup>2</sup>. The boilers have fixed grates with underfire air. Movable grates could probably have been used to advantage to avoid startup and shakedown problems when the boilers were first put into service. Some of these problems were not fully resolved until the computerized controls were added.

At an installed cost of around \$375,000, the plant provides steam to generate hot water for space heating, bathrooms, a laundry, and a large swimming pool. The conference center included more than 144,000 ft<sup>2</sup> of meeting space and 96 guest rooms, and this was expanded to 128 guest rooms. To maintain balance in demand for steam year round, steam is used to produce chilled water for air conditioning during the summer. Water is chilled through a process in which water is used as the refrigerant and fluorochlorocarbons such as freon are not needed. Water is evaporated for cooling, then goes to an absorber vessel where Lithium Bromide (LiBr) absorbs the water. Heat is removed by coolant water. The cool, dilute absorber is pumped to the generator where heat from wood fuel is added. Vaporized water is transported to the evaporator to repeat the cycle.

For the steam-generating system to perform reliably day-in and day-out, the wood chip fuel needs to be consistent in composition and quality. Normally, a cottonwood chip mixture of 40% bark and 60% wood, with a wet-basis moisture content of about 50%, is used. Chips go through the feed system without difficulty unless they are frayed (a result of dull cutting knives) or they become frozen. Because the bin is large enough to store 4 or 5 days' worth of chips and low temperatures do not normally last more than 2 days, frozen chips are rarely a problem. The system burns between 8 and 10 tons of chips daily.

Boiler output can be decreased and operate efficiently with a turndown ratio. For example, a turndown ratio of 3 to 1 allows a 4,000-pound/hour boiler to be operated as low as 1,333 pounds of steam/hour. With proper use of the computer controls, however, it can be operated satisfactorily at 500 pounds of

steam/hour. One person needs to be in attendance around the clock to make sure everything continues to operate within acceptable limits.

Ash from cottonwood is fine and thus is deterred from emission as excessive particulate by keeping excess air to a minimum and separating ash particles out. A cyclone emission control is used. Ash is disposed mainly in a landfill, but some is bagged and sold as fertilizer.

## **Frequently Asked Questions**

*1. What are the main advantages for using small wood-burning boilers for space and/or water heating, electricity generation, and chiller operation over fossil fuels?*

Wood fuel has several environmental advantages over fossil fuels. The ability of wood to be continually replenished leads to a sustainable and dependable supply. There is no net production of carbon dioxide (CO<sub>2</sub>) from wood combustion since the CO<sub>2</sub> generated during combustion of the wood equals the CO<sub>2</sub> consumed during the lifecycle of the tree when transportation fuel is not considered. Wood fuel contains minimal sulfur or heavy metals, and it is no threat to acid rain pollution particularly when compared to coal combustion. Particulate emissions from wood are controllable.

*2. Can wood fuel be economically advantageous?*

In 1985, fossil fuels began selling at low rates on the international markets. This made economic competition for renewable biomass fuels difficult. Wood fuels could compete in cases where wood has low value, for example, thinning material from overstocked stands or undesirable undergrowth in forests, transportation costs for residue wood are favorable, and long-term supplies are available. More recently, natural gas prices have escalated, and in 2004, oil prices rose to their highest level on international markets. Now, it is easier for wood fuel to compete.

When electrical costs are high, wood fuel for power generation is competitive. This can be true even where grid electricity is available as, for example, when demand charges are high for short periods of peak usage.

*3. How costly are wood-burning facilities?*

Costs of installations are highly variable because of different types and capacities of equipment, as well as whether equipment is new or used or already in-place using alternate fuels but can be converted to burn wood. Also, costs for wood fuel systems depends on the level of automation with three basic levels: manual loading, semi-automatic, and fully automatic. In the 1990s, facilities to burn wood in schools cost between \$118,000 and \$465,000. In 1999, the list price from one company for a fuel burner with a maximum energy input of 5 million Btu/hour was \$56,000. Today, complete wood fuel burner/boiler packages are estimated to cost \$50 to \$75 per pound of steam generation per hour, or \$50,000 to \$75,000 per million Btu/hour of heat input. An important aspect of wood energy is that a fossil fuel backup is typically installed for commercial units because of the necessary reliability. A list of installed costs for wood-fired boiler systems is maintained on our website ([http://www.fpl.fs.fed.us/tmu/Wood-Fired\\_Boiler\\_Sizes\\_&\\_Costs.htm](http://www.fpl.fs.fed.us/tmu/Wood-Fired_Boiler_Sizes_&_Costs.htm)).

*4. Are wood-fueled facilities difficult to operate and maintain?*

Wood-burning installations can be automated so operator control is minimal. However, an operator needs to be on call in case of problems; for example, inconsistencies in fuel although fossil fuel backups are typically installed or already available in case of an unexpected malfunction. Furthermore, fossil fuel facilities also need to have a person on call to answer alarms. Maintenance, such as cleaning boiler tubes and upkeep of storage, metering, and control components, would not be expected to be excessive for wood.

*5. Can dependable wood fuel supplies be made available over the long term?*

Wood is a renewable resource; therefore, wood growth can be sustained and supplies will always be available. Ultimately, fossil fuel supplies will be exhausted. In the past, supplies of natural gas have been interrupted or curtailed. Ensuring long-term contracts for a wood fuel supply is highly recommended. A dependable wood fuel supply is vital for ensuring long-term operation of the wood fuel facilities. Some states, like Vermont, are dedicated to finding alternative wood fuel supplies for their school wood heating systems. There is some effort to grow trees in short rotation intensive Silva culture plantations to provide scheduled deliveries over the long term.

*6. Are emissions from wood-burning facilities harmful and difficult to control?*

Most common emissions from wood-burning installations are particulates. These can normally be controlled with cyclones or cyclones in combination with more costly facilities such as dry scrubbers, wet scrubbers, electrostatic precipitators, or bag filters. Advanced combustors minimize emissions generated by burning the wood fuel more efficiently. Visible emissions from the stack during the winter are typically water vapor contained in the wood fuel condensing when entering the cold atmosphere. If emissions are visible during the summer, the wood fuel may not be completely combusted.

*7. Is disposal of wood ash a major problem?*

Wood has significantly lower ash content than coal. Normally, ash from a wood fuel does not contain hazardous material and poses no land filling problems. Alternatively, due to its composition, it might be possible to bag and sell wood ash as fertilizer. Alternative markets ought to be explored.

*8. Can wood-burning facilities regulate to account for fluctuations in heat demand because of varying seasonal heating loads or other reasons?*

The normal turndown ratio for wood-burning facilities is 3:1, although ratios of 20:1 have been obtained. Turndown ratio is the ratio of fuel used in the combustor between high-fire mode and pilot mode that maintains proper combustion temperature and does not cause the system to smoke.

*9. How should wood-burning facilities be designed for the most economical and trouble-free operation?*

There is a wide variety of available equipment and type of wood fuel. Further variability results from type of demand. The more consistent the wood fuel supply and the demand for heat, the simpler the design process. To arrive at the best wood-burning system for a given application, all of the varying design factors must be integrated and controlled. Facilities ranging from 1 million to 5 million Btu/hour will require different kinds of equipment than will larger or smaller facilities.

*10. Can all types of wood be used as fuel?*

No. Wood fuels with moisture contents greater than 60% (wet basis) typically cannot be burned reliably although dual fuel systems could handle the higher moisture wood fuel.

*11. What safeguards are available to ensure a quality wood energy system is constructed?*

Our wood energy specialists at the Forest Products Laboratory use a standard form that can be distributed to interested parties, contact Rick Bergman for a copy. Completing the form requires the manufacturer to construct a reliable wood energy system to meet your energy needs.

*12. Why does wet firewood smoke?*

Wet firewood leads to increased smoke is that the heat required to evaporate the water before the wood will burn lowers the temperature of the fire causing incomplete combustion. If the wood is so wet that good combustion fails to take place at all, the fire will smolder and produce large quantities of smoke.

Experience suggests that most wood stoves/furnaces will burn wood with up to 20% moisture without noticeable increases in smoke (good air-dry wood has about 15% moisture). From 20% to 25% moisture, smoke starts to increase, and by 35% to 40% moisture large quantities of smoke will be produced, even if the heater is otherwise operated carefully.

Freshly cut wood from living trees has a moisture content of approximately 50% (half water). If cut to firewood lengths and stacked in the open it takes roughly 12 months for the moisture content to drop to acceptable levels (i.e., less than 20%). Precise drying rates vary from one wood species to another and are climate dependent (warm and windy with low humidity is best). A roof to prevent rain wetting will speed drying, but ventilation is more important than cover. Do not cover the woodpile with plastic or a tarp as this creates a high humidity region drawing moisture out of the soil.

*13. Are there individuals available to give presentation or assistance for providing information on available wood energy technology including gasification?*

Yes, contact [Rick Bergman](#) or [John Zerbe](#) at the Forest Products Laboratory (608–231–9477/9353).

*14. How much wood fuel is needed for a residential dwelling for a typical winter?*

Assuming 100 million BTUs is the amount of energy needed for a house during a typical winter as space heat, plan on using 4 full cords (128 cubic feet) of oak firewood, air-dried to 20% moisture content. A full cord of air-dried oak is approximately 25 million BTUs. For softwood species like pine, plan on using 7 full cords because a full cord of air-dried pine is 15 million BTUs. Typically, one can mix hardwood and softwood species depending on what type of heat is desired. Softwoods burn fast and hot due to high resin content. Hardwoods burn slow due to their density. These estimates apply for a moderately sized insulated house in southern Wisconsin with a modern, efficient wood-heating appliance.

*15. How is firewood sold?*

Firewood is sold typically three ways: (1) by the full cord of 128 cubic feet which is a standard cord (8 ft x 4 ft x 4 ft), (2) by the face cord (1/3 of a full cord) to allow the firewood cut to 16-in. lengths to be

directly added to the wood furnace and stove, and (3) by the fireplace bundle (fraction of cord; e.g., 1/64 cord is 1 ft by 1 ft by 2 ft). Although the full cord is measured at 128 cubic feet, please allow for void (air) space that reduces the actual volume to an average of 80 cubic feet (60 to 90 cubic feet potentially).